INTERIM REPORT

ON

RADIOLOGICAL WATER POLLUTION

IN THE

ELLIOT LAKE AND BANCROFT

AREAS

1966

ONTARIO WATER RESOURCES COMMISSION

RADIOLOGICAL PROGRAM

INTERIM PROGRESS

REPORT

1966

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CHAPTER I

INTRODUCTION

This interim report summarizes the work to date and presents findings and guidelines for future investigations in the radiological program in the Elliot Lake and Bancroft uranium mining areas.

The survey is made in keeping with the recommendations presented in the report (1) by the Committee of Deputy Ministers on November 24, 1965. The committee was established by the Prime Minister of Ontario, the Honourable John P. Robarts, Q.C., to assess the problem of radiological pollution of water in the two mining areas. In its report the committee recommended that a survey be carried out with the following objective.

> "A detailed investigation of watercourses and waste disposal in both the Elliot Lake and Bancroft areas should be undertaken by the Province, and the present program of monitoring and analysis of mine and mill wastes, surface waters, and drinking water supplies be expanded and extended on a long-term continuing basis."

The program which was started in May 1966 is being carried out in co-operation with the Ontario Department of Health. It is co-ordinated by the Water Quality Surveys Branch of the Sanitary Engineering Division of the OWRC. The survey was planned to extend over a three year period to obtain a complete evaluation of the problem with full consideration of the effects of seasonal variations in the water quality and physical environment.

Discussion in this report will deal primarily with the Elliot Lake area where three uranium mines are still operating. All mines in the Bancroft area are inactive at the present time.

SUMMARY OF FINDINGS

The preliminary data indicate that the Serpent River Basin has been affected by the wastes from the uranium mining industry in the Elliot Lake area. Generally, the degree of radiological and chemical pollution varies inversely with distance from the uranium mines. The average radium-226 concentrations which range from 2 to 98 pci/l show a considerable increase over the estimated background level. The changes in chemical quality were lesser in degree but quite pronounced, particularly in the vicinity of the overflows from the tailings areas.

The greatest impairment of the waters of the Serpent River System was found in the Quirke and Pecors sub basins. However, the preliminary data indicate slight improvement in the conditions of these sub-basins if compared with the levels shown in the Deputy Ministers' report. The overflow from the Long Lake tailings area appears to be the main source of pollution of Quirke Lake at the present time, but the Strike and Bud Lake areas, especially the latter with the reactivation of Algom Quirke Mine, are also contributing pollution. Further examination of the tailings areas will be carried out in the course of the three year study to evaluate the effectiveness of the barium chloride ($BaCl_2$) treatment at Long Lake by Denison Mines Limited and to determine in greater detail the characteristics of the overflows from Bud and Strike lakes prior to dilution with uncontaminated water.

Pecors Lake presently contains a higher level of Ra-226 than Quirke Lake. The main threats to this lake are the effluents from Crotch Lake and the Stanrock tailings area which enter via May and Hough lakes. These two sources will be examined in detail to determine if the radium and chemical content can be reduced.

The Ra-226 level in Elliot Lake has shown a decreasing trend during the past six years. During this survey period the lake has remained within the OWRC Drinking Water Objectives guide level of 3 pci/l although the level in the tributary Sherriff Creek averaged 21 pci/l. The possibility of constructing additional control facilities along the creek will be studied.

Based on operating results, the $BaCl_2$ treatment system operated by Rio Algom Mines Limited is very effective in reducing the Ra-226 level of the effluent discharged to Buckles Creek from the Algom Nordic Mill tailings area. Work is proceeding to evaluate the effectiveness of this treatment on the quality of Nordic Lake.

The extent of pollution in the Bancroft area has reduced significantly when compared with values shown in the Deputy Ministers' report. Only the waters receiving direct tailings discharges show higher Ra-226 levels. Monitoring on this area will be continued to obtain a full evaluation of conditions with seasonal changes.

Preliminary data from the biological survey indicate that the uranium mining industry has had adverse affects on the aquatic biota in the Serpent River systems. However, the available data are limited and this aspect of the program will be pursued actively during the summer of 1967.

The inaccessibility and lack of suitable structures have made streamflow measurements at certain locations in the Serpent drainage basin difficult. Improvements in this situation are to be made in the second year of the study,

In summation, the preliminary data for 1966 illustrate the present extent of pollution in the drainage basins at Elliot Lake and Bancroft. The future work and final report in 1969, will lead to the complete evaluation of the pollution problem and the establishment of future guidelines for its control.

BACKGROUND

The Elliot Lake mining area lies within the drainage basin of the Serpent River in the Algoma District of Ontario. Uranium bearing ores were first discovered in the area in 1953 and with the great demand for uranium at that time the mining companies carried out a crash program to develop these deposits. Intensive mining operations began in 1957 and at its peak 11 mines were operating. Since then, a severe cutback in the world demand for uranium has occurred and consequently, the number of operating mines has declined.

Two of the three operating companies mine uranium while the third recovers its product by the bacterial leaching process. A fourth mine, the Pronto Division of Rio Algom Mines Limited, has discontinued uranium mining and is recovering copper from a nearby property at Spragge. The Rio Algom-Quirke Mine will be reactivated in the near future with the completion of a second shaft now under construction.

Since 1957 the Commission has maintained surveillance over the waste control operations at each mine. At first, attention was paid to the physical containment of the tailings, and regular examination of the receiving waters for chemical pollution. Investigation into possible radioactive contamination of water supplies used for human consumption in the Elliot Lake area was begun by the Ontario Department of Health in 1958.

In 1963 a biological survey by the Commission showed that in some areas of the Serpent Basin the radium content was significant and that wastes from the uranium milling operations had had a profound effect on the biota.

As a result of the findings of these earlier surveys the Committee of Deputy Ministers was established and published its report in November 1965 which recommended the undertaking of this detailed study.

PROTECTION GUIDES FOR RADIOACTIVITY IN WATER

During the past decade much attention has been focussed on the protection of the public against unnecessary and excessive external and internal exposure to ionizing radiation. Several international agencies have set up guides and regulations towards controlling the level of exposure. Although slight differences exist among the values set up by some of the agencies, all of them have followed the general trend of lowering the guide levels for the various radionuclides. Copies of the guides (3,4,5,6,7,) and discussions (8,9) thereof by authorities on radiological health are readily available. The Report by the Deputy Ministers Committee presented a discussion on the guides and should be referred to for more detail. The Drinking Water Objectives of the OWRC (10) lists the guide level for Radium-226 as 3 pci/1.

The Ontario Department of Health short-term objectives propose the reduction of the Ra-226 level to a range of from 10 to 3 pci/1 for drinking waters and 30-10 pci/1 in lakes and streams where present levels are in excess of this range. The longer term objective, of course, is to reduce the Ra-226 concentration to as low a level as possible in accordance with the long standing policy that "unnecessary exposure to radioactivity be kept to a minimum".

CHAPTER 2

FIELD SURVEY

INTRODUCTION

When dealing with water pollution, consideration must be given to not only water quality changes, but also aquatic biota, bottom deposits, sources of pollution and hydrological aspects. A water sample provides an instantaneous account of the chemical and radioactive quality of the water at the time of sampling. This when supplemented with bottom sediment sampling gives an indication of the past history of the degree and extent of pollution. Biological samples exemplify the effects of pollution during the entire life history of the organism. Aquatic organisms concentrate radionuclides as a function of the levels in their environment; but primarily reflect dissolved radioactivity in the water.

The objectives and results of the survey will be discussed under the following headings.

Hydrological Aspects

Water Quality Investigations

Biological Survey

All radiological analyses are being performed by the Ontario Department of Health, Environmental Health Laboratories, Radiation Protection Branch. The analyses include measurements of Ra-226, gross alpha, gross beta, and U-238 in both the dissolved and suspended forms. The analyses on suspended portions are limited to samples which show significant suspended activity. All chemical analyses are performed at the OWRC Laboratories.

The radiological and chemical results have been recorded in a manner suitable for future electronic data processing.

I HYDROLOGICAL ASPECTS

Introduction

A study of the effects of pollutants should take into consideration the hydrology of the receiving watercourse. When wastewaters are discharged at a constant rate, most damage is caused during low streamflow periods; therefore, the predictions of the frequency of the low flow occurrence is important. Under high flow conditions the transport of solids becomes significant. High flow velocities and associated scouring action redistributes solid matter settled during low flow periods. This may be important in areas where accidental tailings spills and/or other significant radioactive discharges in solid form occur or have occurred and could have a pronounced effect on radioactive levels in water.

Since little past flow data for the Serpent River and Upper Eels Creek-Crows River basins are available, the Hydrologic Data Branch of the Division of Water Resources has established a number of flow gauges in both areas.

Survey Work

Twenty-one sites in the Elliot Lake area and seven in the Bancroft area were investigated for the possible installation of manually operated gauges for discharge measurements.

In the Elliot Lake area, one automatic recording gauge was installed near the mouth of Serpent River by the Water Resources Branch, Federal Department of Energy, Mines and Resources. Eight staff gauges and six measuring points were installed by the Hydrologic Data Branch. Five additional sites are to be examined for possible gauging location. A total of 105 streamflow measurements were taken during 1966 at Elliot Lake. Low flow rating curves have been established for the eight staff gauges. However, limited access prevented the development of rating curves for the six measuring points.

Difficulties have been experienced with the measurements of high flows. It is expected that this problem will be resolved during this year.

Six staff gauges were installed in the Bancroft area. Thirty streamflow measurements were taken in 1966. Partial rating curves have been developed for all gauges.

The taking of flow measurements will carry on in an effort to maintain continuity of data for the full range of flows and the development of accurate rating curves. The installation of two additional automatic recording flow gauges is under consideration for the Elliot Lake area at the outlets of the Elliot Lake basin, and the Pecors Lake basin. In the Bancroft area recommended sites are the Crowe River near Chandos Lake and Eels Creek downstream from Highway 28.

II WATER QUALITY INVESTIGATIONS

An extensive sampling program was established to monitor the waters in the Elliot Lake and Bancroft areas in order to determine the extent of chemical and radiological pollution. The sampling sites were selected at locations which would provide a qualitative assessment of the effect which the individual mines had produced on the three river basins. The water sampling was supplemented by the collection of sediment samples from areas where accumulations of radioactive solids were suspected.

After the completion of one year of sampling the data will be assessed and the significance and necessity of the established sampling stations reviewed. New stations may be added and other ones revised at that time.

1. FIELD WORK

Water Samples

Sixty-three sampling stations were selected in the Elliot Lake area and twenty in the Bancroft vicinity. During the month of June, 1966, weekly composites (two samples) were collected from all stream sampling stations at Elliot Lake. A similar concentrated sampling program was carried out in the Bancroft area in July. Subsequently, all stream stations were sampled once a week and the samples composited monthly. All lake stations were sampled once a month. Comments are provided on the data available up to the end of 1966.

Sediment Samples

An Eckman dredge was used for the collection of sediment samples and the results served as a guide for a core sampling program which was performed during the winter months. A piston type core sampler was used and the samples are being analyzed by horizon to determine the depth of the radioactive deposits. As the laboratory results are not available in time for this report, they will be included in the final report.

Control Stations

The following information was gathered at the Control Stations believed to be representative of uncontaminated waters in the Serpent River Basin in the Elliot Lake area:

Radiological			Chemical		
Ra-226	-	0.3 pci/1	Solids (Total)	-	43 ppm
U-238	-	> 10 ug/1	Hardness	-	19 ppm as Caco3
Gross alpha	-	> 1 pci/1	pH	-	6.9
Gross beta	-	9 pci/1	Sulphates	-	7 ppm
			Nitrates	-	> .10 ppm
			Iron	-	> .11 ppm
			Manganese	-	> .25 ppm

DISCUSSION OF RESULTS

SERPENT RIVER DRAINAGE BASIN

During the period from May 1966 to the end of the year approximately 800 radiological and 400 chemical samples were collected from the Serpent River Basin. A summary of the available data is presented on Figure 1. The values listed on the map are averages based on a range of two to eight samples per station.

The preliminary results indicate the extent of pollution found during 1966. In general, the degree of impairment varies inversely with distance from the sources of pollution. The average radium level ranged from 2 to 98 pci/1 in the lakes of the Serpent River System. The chemical results indicated an increase in hardness, total solids, sulphates, nitrates, iron, and manganese, and a general depression of the pH over background levels.

Since the data are limited at this time no attempt can be made to comment on seasonal changes; however, any unusual changes that were noted are pointed out under the following discussions of the sub basins.

Quirke Lake Basin

Quirke Lake is the largest and northernmost lake in the Serpent River basin directly affected by the uranium mining operations. It receives waste discharges from the Bud Lake and Long Lake area via Rochester Creek. According to the results for the months of July and August, the Radium-226 level of Quirke Lake ranged between 23

and 32 pci/1, and averaged 28 pci/1 respectively. The average Ra-226 level showed a reduction of approximately 25% from the level of 38 pci/1 for the corresponding months during the 1962-1964 period.

Chemically, the Quirke Lake data indicated an approximate fivefold increase in the total solids, hardness and sulphates over the background levels. The pH at 5.7 is one of the lowest in the basin.

The discharges from the Strike and Bud Lake tailings areas averaged 11 and 13 pci/1 of Ra-226 respectively. It should be noted that both effluents are diluted before they enter Quirke Lake. The Strike Lake overflow is diluted by the outflow from the diverted Johnson's Creek. In future, the quality of these effluents will be determined prior to dilution. The Bud Lake area in particular should be examined since the Algom Quirke Mine will be reactivated and will use this area for tailings disposal again.

1. FIELD WORK

The overflow from Long Lake could cause serious pollution of the Quirke Lake basin if its Radium - 226 content and other elements are not reduced to acceptable levels. Prior to the opening of the flume in the dam separating Long Lake from Stollery Lake, the Ra-226 concentration in Stollery Lake and the adjoining reach of the Serpent River ranged from 5 to 13 pci/1 (average 8). Since the flume was opened in August the concentration increased to the range of 20 to 59 pci/1 (average 41) in the same waters although the overflow is treated with $BaCl_2$. Chemically, solids increased to approximately 500 ppm, hardness from 72 to 300 ppm, sulphates from 62 to 450 ppm, while the pH dropped from 6.5 to 5.3.

Sediment Samples

The above results illustrate the serious effect the overflow could have on the receiving watercourse and point out the need for strict pollution control measures in this area. Surveillance of the basin will continue to evaluate the effects of the outflow from Long Lake and the reactivation of the Quirke mine on water quality.

Pecors Lake Basin

This basin receives drainage from Crotch Lake and the Stanrock tailings areas in addition to the outflow from Quirke Lake via Whiskey Lake.

The Whiskey Lake average Ra-226 concentration was measured at about 25 pci/1 which is a 10 per cent reduction from the Quirke basin. Dilution is likely the main factor for the quality improvement.

The data for Pecors Lake indicate a slight increase in Radium-226 compared to Quirke Lake. This is likely caused by the pollution from Crotch Lake and the Stanrock tailings area as illustrated by the following:

Radiological

	Ra-226	Gross Alpha	Gross Beta	U-238
Stanrock	41 pci/1	3600 pci/1	2100 pci/1	600 ug/1
Crotch Lake	141 pci/1	210 pci/1	165 pci/1	16 ug/1

Chemical

	Total Solids	Hardness	Sulphates	pH	Fe	Mn
Stanrock	2514	1030	1502	3.0	151	.57
Crotch Lake	596	346	357	5.3	.71	.49

Note: All chemical results except pH reported in ppm.

A comparison of the above Ra-226 values with those shown on the Deputy Ministers' Report shows a significant decrease in radioactivity. The Stanrock level averaged 290 pci/1 during 1961 to 1965 and Crotch Lake 340 pci/1 during 1962 to 1965. However, radium levels in Pecors Lake appear to be relatively unchanged from those in earlier reports.

Since the measured Ra-226 and U-238 concentrations of the Stanrock effluent do not account for the high alpha activity, the presence of other alpha emitters in significant quantities is suspected. Identification of these unknown radioactive elements is being attempted in the Department of Health laboratory. Investigation of possible measures to control pollution further from these sources are planned for 1967. Improved containment of the overflow along with the possible use of $BaCl_2$ treatment will be considered from Crotch Lake.

Elliot Lake Basin

The Elliot Lake basin is affected by Sheriff Creek drainage. This creek drains the Milliken, Lacnor, Stanleigh and Nordic mines properties. Elliot Lake demands constant surveillance since the water is used for municipal supply by the Township of Elliot Lake. The available data indicate that the Ra-226 level in Elliot Lake has remained below the OWRC drinking water guide level of 3 pci/1 although Sheriff Creek has been in the order of 21 pci/1. Most of the radioactivity in Sheriff Creek appears to originate from the branches extending towards the Milliken, Lacnor and Stanleigh mines. This shows an improvement over the value reported in the Deputy Ministers' Report.

Esten Lake

Esten Lake receives the outflow from Elliot Lake and Nordic Lake. The latter receives the treated discharge from the Nordic Mine tailings area via Buckles Creek. The results from the sampling station at Highway 108 indicated that the treatment has been effective in reducing radioactivity in Buckles Creek.

The available data on Nordic Lake indicate that Ra-226 levels in this lake near the inlet of Buckles Creek are in excess of the levels in the creek at the Highway 108 sampling point. It is suspected that leaching of Ra-226 from bottom sediments takes place in the creek between Highway 108 and the lake. Additional sampling stations have been established to confirm this phenomenon.

The radium level in Esten Lake averaged 4.2 pci/1 which is about twice as high as the concentration in the outflow from Elliot Lake. Further downstream at the outlet from Depot Lake the Ra-226 concentration was measured to be 2.2 pci/1.

McCarthy Lake Basin to Serpent Harbour (Lake Huron)

McCarthy Lake receives the outflows from Depot and Pecors lakes. The Ra-226 level in this lake varied from 8 to 17 pci/1 the higher value occurring near the Serpent River inlet from Pecor Lake. In comparison with background levels, changes in chemical quality were evident.

From McCarthy Lake the Serpent River flows through a chain of smaller lakes, crosses Highway 17 and enters Lake Huron at Serpent Harbour. The Ra-226 concentration near the inlet of Serpent River averaged 9 pci/1.

The radium level of 16 pci/1 and the chemical quality of the overflow from the Pronto tailings area are considerably in excess of background levels.

UPPER EELS CREEK - CROW RIVER BASIN

Approximately 100 radiological and 85 chemical samples were collected from the upper Eels Creek-Crow River basins during the period from July 1966 to the end of the year. The available data are summarized on the enclosed map of the Bancroft area. Although limited the data illustrate that pollution in these two basins is not as serious as in the Serpent River Basin.

Only the waters receiving direct discharges from the tailings areas showed significant Ra-226 activities. These included Bentley, Deer and Farrel creeks along with Bow Lake and Inlet Bay of Paudash Lake. In the above waters the Ra-226 level varied from 3 to 11 pci/l. In the remaining part of Paudash Lake, Eels Lake, and the downstream watercourses the radium levels were below 3 pci/l. Comparing with the levels shown in the Deputy Ministers' report, the concentrations in the above waters have reduced significantly.

The monitoring program will be continued to obtain a complete evaluation of the chemical and radiological water quality in the Bancroft area.

III BIOLOGICAL SURVEY

REVIEW OF PRELIMINARY INVESTIGATION IN 1963

A comparison of gross alpha activity in samples representing several levels of the biotic community of lakes in the Elliot Lake area indicated that the biota had concentrated radioactivity. Indeed, alpha activity in samples of filamentous algae from Quirke Lake was 140 times that of Dunlop and similar samples from Pecors Lake averaged 35 times that of Dunlop. One sample of clams from Pecors Lake showed an alpha activity of more than 400 times that of surface water from the same sampling point.

In addition to the accumulation of radio-nuclides, the relative availability of fauna suggested depressed bottom communi ties in terms of numbers of both individuals and species, particularly in Quirke Lake.

OBJECTIVES OF THIS SURVEY

The 1966 phase of this three year program had the following objectives:

1) determination of differences in basin productivity in uncontaminated lake waters and those affected by uranium milling wastes.

2) evaluation of the relationships between pollution and physicochemical characteristics of lakes and streams, and plankton, bottom fauna, and fish populations.

3) determination of the impact of uranium milling operations on the population dynamics of fish.

4) significance of the levels of radioactivity in whole fish and fish flesh samples.

5) determinations of the concentration of radioactive isotopes in specific taxa to validate the use of biological sampling in monitoring radioactivity.

In addition, portions of the 1967 and 1968 field work will be designed to provide an understanding of those waste substances which are detrimental to life in the receiving waters, in order that specific recommendations may be formulated for control

METHODS

Twenty-one stream stations on the Serpent River watershed were selected for biological examination and sampled three times during the summer. On the first visit, filamentous algae and macro invertebrates were collected. Caddisfly larvae and crayfish were found to be most abundant at most stations and efforts were made to collect these two forms only. Sampling effort was kept constant to provide an estimation of relative abundance. Samples were immediately labelled and frozen which was essential for subsequent radiological analyses.

An analysis of the gill net catches per unit of effort will provide a relative estimate of standing crop of fish in the study lakes. Radiological measurements will be performed on the following biota:

1) filamentous algae from stream stations,
2) caddisfly larvae from stream stations,
3) crayfish from stream stations,
4) midge larvae from lake stations,
5) whitefish fillet samples from lakes,
6) whitefish whole fish subsamples from lakes,
7) miscellaneous biota including clams, some oligochaetes, northern pike and lake trout.

A similar biological survey program was carried out in the Bancroft area. Samples of sediment, plankton and bottom fauna were collected once during the summer from 12 lake stations representing six lakes. Fish from the six lakes were obtained by personnel of the Department of Lands and Forests. Filamentous algae and plankton samples were collected from eight stream stations. Identifications were made and selected taxa were submitted to the Department of Health.

RESULTS

Only a limited number of radiological analyses of fish samples from the Elliot Lake area were completed in time for inclusion in this report. Gross alpha and beta activities in whitefish samples from the Serpent River System were measured, but without identifying the particular isotope(s) involved the significance of the levels present is not apparent.

Whitefish samples from Dunlop Lake showed a gross alpha activity of less than 0.1 picocurie per gram (pci/gm) for all determinations, except one wholefish subsample. In Quirke Lake, on the otherhand, whitefish had a gross alpha activity averaging more than four times that of Dunlop Lake.

The same type of samples from Pecors Lake contained lower concentrations of radioactivity than Quirke Lake. The levels were, nevertheless, significantly higher than those of the control lake.

The radioactive concentrations in fillet samples were lower than in wholefish samples. If, as is suspected, radium 226 is the major radioactive contaminent, this would appear to be logical as radium is primarily a bone-seeking element.

The results of the measurements for radioactive concentrations in the bottom fauna of lakes and streams, in plankton from the lakes, and filamentous algae from the streams are not available for inclusion in the report. Preliminary assessment of the biological data indicated differences in the relative abundance of the communities sampled. The abundance of organisms in terms of both numbers and species present seemed superficially at least, to vary with distance from the sources of pollution. (Radiological levels in water tend to follow a similar pattern)

DISCUSSION

Notwithstanding the present lack of radiological results on biological samples, the field program related to the initial year's objectives was almost entirely completed. Comparative primary productivity measurements using the C-14 light and dark bottle technique were completed in Dunlop Lake and Quirke Lake and data are now being evaluated. Numerous samples of the biota were collected for radiological analyses to determine what taxa might be most appropriate for monitoring radioactivity levels. Fish were collected for radiological determinations and fish sampling was conducted to determine possible effects of uranium mining on the dynamics of fish populations. Further studies in this regard are planned.

The part of the study dealing with the effect of milling contaminants on benthic communities was not completed satisfactorily Unit collections at each station were taken for both taxonomic purposes and radiological measurements because of the general paucity of fauna in these oligotrophic lakes. Unfortunately, the freezing technique required for radiological analyses proved to be somewhat less useful than was originally anticipated. Oligochaetes, which were generally predominent in the collections were mutilated by the freezing process and many other fauna were rendered unidentifiable.

Other preserving techniques are now being investigated. If a suitable preservative is not found, it may be necessary to collect separate samples of benthic communities for radiological measurements and taxonomic purposes during the 1967 program

Since radioactivity may have a genetic effect as well as the more obvious somatic effect, which can be measured in the existing generation, an experiment is being designed to compare hatchability of lake trout eggs from parent stock in Quirke and Dunlop Lakes and thus isolate the subtle genetic effects if they are present. Co-operation from the Department of Lands and Forests will be necessary and deliberations with the department are now in progress.

CHAPTER 3

MILL SURVEY

INTRODUCTION

This section provides a general description of the milling process employed by the operating mines in the Elliot Lake area. The three mines in the Bancroft area have been abandoned. This is followed by a discussion of the uranium mines in the Elliot Lake and Bancroft areas. Emphasis is given to the sources, nature, containment and treatment of the wastes. The locations of the mines are shown on the enclosed maps.

Table I at the end of this section summarizes the dates of operation and production capacities along with the locations, volumes and estimated Ra-226 contents of the tailings areas of the uranium mines in the Elliot Lake and Bancroft areas.

MILLING OF URANIUM ORE

The milling or concentrating of uranium is divided into four distinct steps: crushing and grinding of the ore; leaching of the ground ore with sulfuric acid to dissolve the uranium; extraction of the uranium from the solution by ion exchange; precipitation of the uranium as diuranate and packing for shipment.

Crushing and Grinding

The ore is crushed to less than 5/8 inch in size and then ground to less than 65 per cent minus 200 mesh. The pulp, in slurry form, is dewatered in neutral thickeners in preparation for leaching.

Leaching

The sulphuric acid leaching process is used by the uranium mills in Ontario. The ore pulp is heated to 170°F and leached for about 40 hours with the acid and oxidized either by air, or by an oxidizing agent such as sodium chlorate. After leaching, the pulp is diluted to about 55 per cent solids and the pH adjusted to a value of 2. The pulp is then pumped to wash thickeners, which separate the barren rock from the uranium-bearing solution. The solution is conveyed to the ion exchange section, while the dewatered slurry is filtered and washed twice to remove any traces of uranium. The solids or tailings are then neutralized and pumped to disposal.

Ion Exchange

Before this stage of the mill process the uranium-bearing solution is clarified further to remove all traces of suspended material. The clarified solution is pumped through an ion exchange column to extract the uranium. Subsequently, the barren solution may be reused for removal of yttrium and/or thorium before it is neutralized with lime and discharged to waste. The uranium is then stripped from the ion exchange resin with nitric acid. The nitrate radical replaces the uranium on the resin and a clear concentrated solution of uranium results. This solution (the eluate) is then partially neutralized with lime, adjusted to a precise pH with ammonia to precipitate iron. It is then filtered to remove the iron together with any insoluble calcium sulphate. The calcium sulphate and iron are returned to the main leach circuit for recycling. The upgraded eluate is further neutralized with ammonia to a pH of 7 to precipitate the uranium, as ammonium diuranate.

Drying and Packaging

The diuranate or "yellowcake" is thickened, filtered and washed before it is dried. It is then packaged in drums and shipped to uranium refineries for further procession into uranium oxide.

CHEMICAL USAGE

The following ranges of chemical used per ton of ore milled in the acid lead process have been estimated from data on the Elliot Lake mine.

Sulphuric Acid	67 - 100 lb.
Sodium Chlorate	2 - 4 lb.
Lime as CaO	33 - 46 lb.
Nitric Acid	3 - 5 lb.
Sodium Hydroxide or	1 - 2 lb.
Magnesium hydroxide	- 0.5 lb.
Glue	0.3 - 1.6 lb.
Separan	0.03- 0.05 lb.
Steel rods and balls	3 - 7 lb.
Water	2 - 5 tons.

PROCESS INNOVATIONS HAVING SOME EFFECT ON POLLUTION CONTROL

Water Re-use

Since start-up, mills have made numerous changes which have contributed to re-use of water and thereby a measure of pollution control. Mine water previously discharged to waste is treated to recover a significant uranium content. The Stanrock Mill recovers uranium from mine water employing the bacterial leaching process. At the mines where conventional mining is carried out neutralized mine water is introduced into the milling circuit in the grinding process. Other examples of water re-use include the use of neutral thickener overflow in the grinding mill and spent mine water to slurry tailings for pumping of waste to the disposal area.

Recovery of By-Products

At the operating mines the barren effluent before discharge to tailings is treated to recover yttrium and in one case thorium. After recovery of these by-products the barren effluent is neutralized before it is discharged to waste.

WASTE SOURCES

The uranium ores mined in Ontario contain from 2 to 4 pounds of uranium per ton of ore. For each ton processed, approximately one ton of solid wastes, and two to five tons of liquid waste are produced.

The tailings are neutralized with lime prior to discharge to disposal. The volume of one ton of slurried tailings is estimated at twenty cubic feet.

The suspended solids portion of the tailing slurry settles in the disposal areas and the excess liquid containing primarily dissolved radioactive elements such as radium-226, thorium and others overflows to watercourses. In order to reduce the volume of wastes to tailings areas and the subsequent discharge of radioactivity to the environment treatment of the barren solution with barium chloride separate from the tailings is being practiced. The treated barren solution, its radioactivity being substantially removed, is then discharged directly to watercourses. Another method of minimizing the discharge of radioactivity to the environment is the treatment of the effluent from tailings areas with barium chloride.

TAILINGS IMPOUNDMENT AREAS

The impoundment areas are constructed to contain and store the solid tailings wastes. Natural basins either on land or in lakes have been used as disposal sites, and artificial dams erected where necessary to improve confinement of the wastes. The beneficial effects and undesirable features of tailings areas have been discussed in some detail in the Deputy Minister's Report.

ELLIOT LAKE AREA

DENISON MINES LIMITED

The mill is situated at the western end of Quirke Lake approximately 17 miles north of the Elliot Lake townsite.

The mill, which has a rated capacity of 6,000 tons of ore per day, began production in May, 1957. At the present time, ore is being milled at the rate of 3,000 tons per day. A rare earth recovery plant went into production in January, 1967, and produces 600 - 700 pounds of yttrium daily.

Tailings Disposal

Two separate areas have been used by the company for the disposal of mill tailings. Smith Lake, which lies just west of the mill served as an emergency area when the mill first began production. It is no longer used. The area presently in use is Long Lake which is about three-quarters full. The tailings are introduced at the top end of Bear Cub Lake and flow by gravity to Long Lake. This system drains via a flume at the top of the dam at the western end of Long Lake into Stollery Lake and then into the Serpent River. Barium chloride is added to the effluent at the flume and Stollery Lake is presently used as settling area. Denison has proposed the construction of a dam to divide Stollery Lake to create a settling area separate from the Serpent basin.

After intensive studies of the waste disposal problem, it was found to be more effective to discharge the barren effluent separate from the mill tailings. Since June, 1966, the barren effluent following treatment, has been discharged directly to Stollery Lake.

The volume of mill tailings contained in these areas by the end of 1966 was estimated at 283 million cubic feet. The radium content of this volume of tailings is estimated to be 7.7 pounds.

Consideration is being given by company officials to the long-term aspects of tailings disposal. At the present time tentative proposals centre around the continued use of Long Lake or another alternative involving Stollery Lake. There are several problems with these proposals and to date no definite decision has been reached.

Can-Met Explorations Division

This is a non-operating mine. The mill site is situated on the east shore of the peninsula jutting from the south shore of Quirke Lake. The mill had a rated capacity of 3,000 tons of ore per day. Production began on March, 1958, and terminated in March, 1960.

Tailings Disposal

The tailings disposal area was shared with the Stanrock Uranium Mines Limited. The tailings arrangements are discusssed in the section on Stanrock Uranium Mines Limited.

Based on production figures, it is estimated that the operation of the Can-Met mine contributed almost 40 million cubic feet of tailings (approximately one pound of radium).

RIO ALGOM MINES LIMITED

Nordic Lake Division

This mine is located just east of North Nordic Lake approximately four miles southeast of the Elliot Lake townsite. The mill has a capacity of 3,700 tons of ore per day and began production in January, 1957. Present plans call for the operation of the mill until late 1968, at which time the operations will be moved to the Quirke mine.

Thorium and Yttrium are being extracted from the barren effluent at a rate of approximately 1,000 and 300 pounds per day respectively. After extraction the barren effluent is neutralized and discharged to tailings area at a rate of 0.5-1.0 million gallons per day.

Tailings Disposal

The tailings disposal area of 212 acres is located directly north of the mill site. The original thirty acre tailings site lies directly north of North Nordic Lake and is no longer used. A dam separates the two areas with the newer impoundment at a considerably higher elevation than the former site. Dams located along the southerly and easterly sides define these limits of the tailings area. Tailings are introduced at the northwest corner and also by spigotting along the south and east sides.

By the end of 1966, it is estimated that 230 million cubic feet of tailings containing six pounds of radium were impounded in the combined areas.

Tailings effluent is decanted at the northeast corner and the effluent flows through a series of shallow ponds. Barium chloride is added and the precipitate is allowed to settle in the ponds. The effluent discharges eventually to Buckles Creek which subsequently flows into Nordic Lake.

Quirke Lake Division

This mine is situated at the northern end of Highway 108 on the Serpent River and immediately west of Quirke Lake. The mill had a capacity of 4,500 tons per day and commenced production in September, 1956 and ceased production in February, 1961.

The mine and mill are being reactivated. The No. 1 shaft was dewatered in 1966 and has since refilled. Plans have been made to dewater it again during 1967 following which underground work will be resumed. A second shaft is being sunk and upon completion in 1969, the use of No. 1 shaft will be discontinued. Eventually, all the operations from the Algom Nordic mine site will be moved to the Quirke mine.

Tailings Disposal

The tailings disposal area used by this mine was Bud Lake located to the south-west of the mill site. Seepage from the lake passed through a rock dam and is carried via a creek to the Serpent River.

An estimated 84 million cubic feet of tailings and 2.3 pounds of radium are retained in this area.

The company plans to continue using Bud Lake. The capacity of the impoundment area could be increased by constructing a dam in the northwest area. Treatment of the effluent with barium chloride is planned.

Lacnor Division

The Lacnor mine, formerly known as Lake Nordic Uranium Mines Limited is abandoned and located just west of Dumbell Lake approximately two miles west of the Elliot Lake township.

This mill had a rated capacity of 4,500 tons per day. Operations started in September, 1957 and ceased in June 1960.

Tailings Disposal

The tailings disposal area used by this mill was located in a valley approximately 2,000 feet east of the mill. The valley was dammed at the easterly end to create the impoundment area. The tailings area drains to the Algom Nordic mine tailings area. The discharge from this area receives barium chloride treatment before it enters the Serpent River watershed.

At present, there is little overflow from the Lacnor tailings area except in periods of heavy and/or extended rainfall and during spring runoff.

Based on production figures, the volume of tailings wasted from this mine is estimated at 63 million cubic feet (1.7 pounds of Ra-226)

Panel Division

The former mine site is situated on the north shore of Quirke Lake, approximately 20 miles northeast of the Elliot Lake townsite. The mill was rated at 3,500 tons of ore per day and operated from February, 1958, to June, 1961.

Tailings Disposal

The tailings were discharged into a swampy area located in the southwest corner of Strike Lake, approximately one mile north of the mill site. From there, the drainage flowed into Quirke Lake via Rochester Creek. Tailings were also discharged to a small lake located about 1/3 mile south of Strike Lake.

At shutdown, the tailings occupied almost one-half of Strike Lake. Since then, this system has not been maintained to prevent exposure to drainage from Rochester Creek.

There is estimated to be 71 million cubic feet of tailings in the area containing about 1.9 pounds of radium.

Milliken Division

This non-operating mine is situated to the west of Sheriff Lake about two miles northeast of the Elliot Lake townsite.

Production began in April, 1958, and discontinued in June, 1964. The mill had a capacity of 3,000 tons of ore per day. In the latter stages of operation, limited bacterial leaching was carried out.

Tailings Disposal

The Milliken mine together with the Stanleigh mine used Crotch Lake for waste disposal. During the operation of the two mines an estimated 165 million cubic feet of tailings containing approximately 4.5 pounds of radium were discharged to the east and west arms of the lake. The tailings filled the west arm of Crotch Lake completely and about one half of the east arm. A dam was constructed to contain the tailings in the west arm.

The outflow from Crotch Lake flows through a series of lakes in the Serpent River system and into Pecors Lake.

Some tailings from the Milliken operation were also discharged into Sheriff Creek whenever pumping problems occurred on the tailings line to Crotch Lake. Sheriff Creek drains Sheriff Lake and flows into Elliot Lake.

Preston Mines Limited - Stanleigh Division

This abandoned mine is situated just east of the Milliken mill site beside Penelope Lake about two miles north of Elliot Lake townsite.

The mill had a capacity of 3,000 tons of ore per day and operated from March, 1958 to January, 1960.

Tailings Disposal

The tailings disposal area used was shared with the Milliken mine. A separate pipeline conveyed the tailings to Crotch Lake.

This mill contributed an estimated 50 million tons of tailings and 1.4 pounds of radium to the lake basin.

Spanish American Division

The mine is located on the west shore of Quirke Lake. The mill had a rated capacity of 2,000 tons of ore per day. Production began in May, 1958, and closed in February, 1959.

Tailings Disposal

The tailings disposal area used was Olive Lake. A dam at the westerly end of the lake created an impoundment area and the effluent flowed via a small creek into Long Lake. Drainage waters continue to flow into Long Lake.

It is estimated that the impoundment contains about 3 million cubic feet of tailings and 0.1 pounds of radium.

Pronto Division

This property is located in Long Township just north of Highway 17, approximately 15 miles east of the Town of Blind River. This division of the company, while no longer mining and milling uranium ore, concentrates copper ore transported from the nearby Peter mine located in Spragge Township.

As a uranium mill, it had a capacity of 1,500 tons of ore per day and operated from September, 1955, to April, 1960. Concentration of copper ore is being carried out at the rate of 700 tons of ore per day.

Tailings Disposal

The L-shaped tailings disposal area is located approximately 2,500 feet from the mill site. The tailings slurry was discharged into the northwest section. No decant facilities were provided during the uranium mining operations and seepage passed through the south dam. The area at first drained to Lake Lauzon but in 1960, the effluent was redirected to the North Channel (Lake Huron).

The volume of uranium mill tailings contained in the disposal area is estimated to be 44 million cubic feet. The amount of radium is estimated at 1.20 pounds.

Copper tailings are now directed to the area and cover the uranium tailings. Improvements during 1966 included the construction of decant facilities and the repair of dams.

STANROCK URANIUM MINES LIMITED

This mine is located on the peninsula at the south shore of Quirke Lake. Bacterial leaching is carried out to recover approximately 600 pounds of uranium oxide per day. Conventional mining operations at a rated capacity of 3,000 tons per day, began in March, 1958, and ceased in November, 1964.

Tailings Disposal

The mill tailings disposal area was shared with Can-Met Explorations (now owned by Denison Mines Limited). It comprises some 150 acres and is located in a valley to the south of the two mines.

Dams have been constructed at the north and south ends to confine the tailings. The decant from the tailings area flows southerly via a small creek into Half-Moon Lake and then through a chain of lakes into Pecors Lake.

There are an estimated 173 million cubic feet of tailings containing 4.7 pounds of radium in the disposal area of which Stanrock has contributed 133 million cubic feet (3.6 pound Ra-266).

Numerous dam failures have occurred during the period of operation. One of the two decant towers failed in July, 1964 and allowed the escape of approximately 250,000 to 500,000 tons of tailings to the low-lying area south of the impoundment. The escaped tailings are exposed to leaching by surface drainage.

Since May, 1965, the mill effluent has been treated with barium chloride prior to its discharge to the disposal area.

BANCROFT AREA

MACASSA GOLD MINES LIMITED

Bicroft Division

The mine is situated some fourteen miles southwest of the Town of Bancroft in lots 27 and 28, Concession II in the Township of Cardiff. It has a capacity of 1,500 tons of ore per day. Production began in November, 1956, and ceased in May, 1963.

Tailings Disposal

Mill tailings from this mine were discharged to three areas. A small emergency site was located south of the mill. A standby impoundment area was created by damming a small valley just west of the mill on the opposite side of Deer Creek. The majority of the mill tailings were discharged into Auger Lake northwest of the mill. Dams were constructed at the north and south ends of the lake to confine the tailings. Drainage from Auger Lake discharges to Deer Creek and then to Inlet Bay of Paudash Lake which is part of the Crowe River basin.

It is estimated that 41 million cubic feet of tailings and 1.4 pounds of radium are contained in these areas.

A detailed inspection of this area is planned for 1967.

CANADIAN DYNO MINES LIMITED

The mine site, located in lot 12, Concession 8, Township of Cardiff, is approximately 18 miles southwest of the Town of Bancroft. The mill had a rated capacity of 1,500 tons of ore per day. Production began in May, 1958 and ceased in March, 1960.

Tailings Disposal

The mill tailings were discharged into a valley located east of the mill. A dam at the south end of the valley confined the tailings.

Liquid effluent from the tailings area flows over a dam via a small creek into Farrel Lake. From there it flows via Farrel Creek into Eels Lake (Eels Creek basin) which eventually joins the Trent River System at Stoney Lake.

The volume of tailings produced has been estimated to be 13 million cubic feet containing approximately 0.4 pounds of radium.

METAL MINES LIMITED

Faraday Mines Division

This mine, located in Faraday Township on the north side of Highway 28 about four miles southwest of the Town of Bancroft, is situated on the northeast tip of Bow Lake. This mill had a rated capacity of 1,500 tons of ore per day and was in production from April 1957 until June 1964.

Tailings Disposal

The mill tailings from this plant were discharged to a L-shaped area located just east of the plant. This area is comprised of some forty acres. It is bounded by dams that effectively prevent the escape of tailings. Bentley Creek, which originally flowed through this area, was diverted around the tailings area. The effluent decants to the Bentley Creek diversion which drains to Bow Lake.

A secondary, emergency disposal area is located to the northeast of the mill.

An estimated 58 million cubic feet of tailings containing about 1.6 pounds of radium are retained in these areas.

ELLIOT LAKE AREA

MINE	DATE OF OPERATION	RATED CAPACITY TONS PER DAY	TAILINGS LOCATION	ESTIMATED VOLUME OF TAILINGS (1×10^6 FT^3)	ESTIMATED Ra-2 CONTAINED IN TAIL
Denison°	May 1957	6,000	Long Lake	283	7.7
Can Met	March 1958-March 1960	2,500	S.E. of Stanrock Mill	40	1.0
RIO ALGOM					
- Lacnor	Sept.1957-June 1960	4,000	2000 Ft.E. of Mill (Valley)	63	1.7
- Milliken	April 968-June 1964	3,000	Crotch Lake	165	4.5
- Nordic°	Jan. 1957	3,700	Above N.Nordic Lake	230	6.0
- Panel	Feb. 1958-June 1961	3,500	Strike Lake	71	1.9
- Pronto	Sept. 1955 *	1,500	E. of Mill(Valley)	44	1.2
- Quirke	Sept.1956-Feb.1961	4,500	Bud Lake	84	2.3
- Spanish American	May 1958-Feb.1959	2,000	Olive Lake	3	0.1
- Stanleigh	March 1958-Jan.1960	3,000	Crotch Lake	50	1.4
STANROCK°	March 1958	3,000	E. of Mill(Valley)	173	4.6
				TOTAL	32.4
			BANCROFT AREA		
BICROFT	Nov.1956-May 1963	1,500	Ager Lake	51	1.4
DYNO	May 1958-March 1960	1,500	E.of Mill(Valley)	13	.4
FARADAY	April 1957-June 1964	1,500	E. of Mill	58	1.6
				TOTAL	3.4

* This mine is recovering copper at the present time

° Operating mine

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LIST OF ABBREVIATIONS

Sr^{90}	-	Strontium 90
Ra-226	-	Radium 226
pci/1	-	Picocuries per liter or 10^{-12} curies per liter
ppm	-	Parts per million
U-238	-	Uranium 238
$BaCl_2$	-	Barium Chloride
ug	-	Micro grams or 10^{-6} gms.